SUSAN M. SHEFFER (D3017-1)

Tapping Tomatoes for Taste

Homogenized tomato fruit sample used for measuring acids, sugars, and vitamin C at the ARS Plant Genetics Resources Unit in Geneva, New York. Researchers there are studying how these various compounds interact to create flavor in tomatoes. This knowledge may help in future efforts to breed a tastier tomato.

Tomatoes are a $2 billion crop in the United States, and we demand a lot from them. No matter where we live, we want fresh, delicious tomatoes to be available year-round. Large-scale producers ship tomatoes long distances, and that makes firmness and long-term storage top priorities for tomato breeders.

Consumers, however, value garden-fresh taste. A common complaint is that tomatoes in supermarkets lack the flavor of locally grown varieties. To improve flavor, breeders need to know more about the varieties that hold the greatest potential for enhancing taste.

Joanne Labate, an Agricultural Research Service molecular biologist, and Larry Robertson, curator of the ARS Plant Genetic Resources Unit vegetable collections in Geneva, New York, joined with Dilip Panthee of North Carolina State University to explore tomato's genetic diversity in a comprehensive study designed to help breeders develop tastier tomatoes.

The team raised many varieties of tomatoes and analyzed them for the compounds that play a role in determining flavor. They also had volunteers evaluate their field-grown varieties for flavor and other sensory characteristics. The study, published in *Plant Genetic Resources: Characterization and Utilization* (2013), represents one of the most comprehensive efforts to identify the sources of genes for boosting flavor among both commercial tomato varieties and breeding lines.

"Commercial tomato varieties have a narrow genetic base. To find ways to improve their flavor, we need to broaden that base and begin looking among our entire stock of tomatoes for new sources of beneficial genes," Labate says.

A Cross Section of the World's Tomatoes

What we refer to as "flavor" in a tomato is actually the interaction and ratios of sugars, organic acids, and volatile compounds derived from amino acids, lipids, and carotenoid precursors. Fructose and glucose are the major forms of sugar. Citric acid is the dominant acid in the ripe tomato fruit, though malic acid is also present.

The researchers wanted to determine the variability of these four compounds from one variety to the next and see how that variability contributes to flavor.

They grew 173 varieties on test plots in North Carolina. The varieties were selected from the approximately 6,000 accessions in the ARS Tomato Germplasm Collection in Geneva because they represent a cross section of the world's tomato diversity. Some were commercial varieties, some were heirlooms, and others were lines used by breeders. All were part of a core collection of tomatoes kept in Geneva that had never been evaluated for fruit-quality traits.

Tomatoes were classified into one of three categories: plum or roma; cherry or grape; or the traditional large, round types. Ten volunteer taste testers were trained in sensory analysis and asked to rate each variety on a scale of 1 to 5 in four sensory areas: odor, taste, flavor, and texture. Taste tests were conducted over 6 weeks. The researchers also measured each variety's firmness and measured juice for levels of sugar, citric acid, and vitamin C.

A Key Ratio: Acid Versus Sugar

The result is a treasure trove for breeders: a comprehensive set of rankings on flavor qualities, sweetness, vitamin C content, sugar and acid content, and other characteristics. The findings show that although thousands of compounds go into determining flavor and other characteristics, two play a key role in determining overall flavor: sugar and acid. While the amount of acid varied only slightly in the tomatoes tested (from 0.2 to 0.64 percent), there was a wide variety in sugar content (3.4 to 9.0 percent). That's important because, for ripe tomatoes, the greater the ratio of sugar to acid, the sweeter the tomato. The sweeter the tomato, the more flavor it contained.

The findings are good news for breeders because they show a broad range of possibilities for adjusting sugar levels and developing more flavorful tomatoes. Breeding to enhance flavor shouldn't be that difficult because both sugar and acid content can be reliably and inexpensively measured, the researchers say.

The North Carolina fields used by the researchers also affected the characteristics observed in the study tomatoes, such as size, shape, and taste. But genes strongly influence such traits, and traits such as flavor are likely to show up consistently in a number of different environments if superior varieties with associated molecular markers are used in breeding, the researchers say.

"The growing environment will affect the expressed traits, but being able to identify and select superior tomatoes for breeding might increase the frequency of favorable alleles being transferred into different varieties and ultimately improving them," Robertson says.

A Statistical Approach

In another study, Labate and Robertson used new statistical genetic approaches to determine when incorporating genes for desirable traits led to inadvertently adding other genes with unintended consequences. The phenomenon, known as "linkage drag," is a common problem for plant breeders, but it is a particular challenge for tomato breeders because so many of the tomato's key horticultural traits originated from wild relatives. Tomatoes originated in Peru, Chile, Ecuador, and Mexico, and they were brought to colonial America through Europe. During the early 20th century, they were crossed with wild species to make the tomatoes we have today.

The researchers were able to identify latent genes that migrated into breeding lines along with genes deliberately introduced to confer desirable traits. The results, published in *BMC Plant Biology* (2012), showed, for instance, how a gene introduced for disease resistance carried with it a gene that influenced fruit ripening. The work sets the stage for more detailed studies on the effects of linkage drag on tomato breeding efforts, elimination of undesirable genes from breeding stocks, and identification of more desirable sets of genes for tomato breeders.

The researchers are optimistic that both studies will provide guidance to breeders interested in developing more flavorful tomatoes. The tomato genome sequence, published in 2012 by ARS scientists and collaborators, is also enabling breeders to use molecular markers to identify and lock in tomato genes that are responsible for desired traits such as flavor.—By **Dennis O'Brien,** ARS.

One of numerous varieties of tomatoes grown and analyzed for compounds that play a role in determining flavor.

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